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HUMAN RESOURCES

LCOM EXPLAINED

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The Logistics Composite Model (LCOM) is described. LCOM is a simulation of an aircraft maintenance organization used to derive manpower requirements for Air Force maintenance units. The paper attempts to acquaint a general audience with an important Air Force model.

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LCOM EXPLAINED

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PREFACE

This paper describes the Air Force's Logistics Composite Model, or LCOM. For LCOM practitioners, the analytic power and appeal of this simulation lie in its ability to deal with the complexity, variety, and uncertainty of the aircraft maintenance world. They don't need an LCOM overview. For interested lay people, understanding the basics of LCOM often requires difficult journeys through arcane detail. This latter group is my target audience.

Corrections and suggestions to a draft received from several colleagues have improved the paper's accuracy and clarity. These were Captain William Weaver, Mr. John R. Plassenthal, Captain Douglas Popken, Major Colleen Gorman, Mr. Mark Hoffman, Dr. Larry Howell, Mr. Richard Cronk, Lieutenent Colonel Paul Cunningham, Captain Raymond Hill, and Captain Gregory Clark. Any errors still found are, of course, my own doing. Mr. Matt Tracy helped Mac-edit the paper, and Mrs. Susan Stiller provided total quality librarianship.

To all, all thanks.

SUMMARY

This paper introduces a general audience to the Air Force's Logistics Composite Model. LCOM is a Monte Carlo simulation of a maintenance organization used to identify optimal base-level resources. An important LCOM application is to determine maintenance manpower requirements. The paper describes the motives and some of the processes of LCOM. Several applications of the model within the manpower, personnel, and training (MPT) analysis domain are also described.

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LCOM EXPLAINED

Introduction

The Logistics Composite Model (LCOM) was created in the late 1960's through a joint effort of The Rand Corporation and the Air Force Logistics Command. The original purpose of LCOM was to provide a policy analysis tool to relate base-level logistics resources with each other and with sortie generating capability. Logistics resources modeled in LCOM include maintenance people, spare parts, and aerospace ground equipment (AGE). LCOM is a flexible and versatile model. The interaction of any of the factors can be studied in virtually any level of detail.

Though intended to examine the interaction of multiple logistics resource factors - hence the "composite" - LCOM's most important use has been in establishing maintenance manpower requirements. A large portion of the Air Force maintenance work force is justified through LCOM simulation. These people are said to be "LCOM-earned." LCOM simulation is connected by Air Force Regulation 25-7 to the manpower standards process, and through this to the Air Force budget.

LCOM software documentation is abundant (e.g., Drake & Wieland, 1982; Aeronautical Systems Division, 1990; Air Force Manual 171-605). [1] And several LCOM training guides have been written (e.g., Dengler, 1981; Keller, 1977). But there has been surprisingly little published focusing on the LCOM manpower estimation process itself. LCOM modeling is often cited as an organizing framework for certain kinds of manpower, personnel, and training (MPT) analysis, but since few people understand LCOM, few understand why this connection with MPT is so apt. Understanding of this simulation has always been limited to a small group of specialists. This essay provides a concise explanation of LCOM for the layperson who wants to understand the general manpower estimation process without having to confront LCOM's legendary details. The objective is to reduce LCOM mystery, not to promote LCOM mastery.

LCOM Simulation Overview

LCOM simulates the work of a maintenance organization. LCOM study objectives may differ widely, but the usual one is to locate the best - or optimal - mix of logistics resources to support a given weapon system under given operating conditions. These logistics resources can

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[1] AFM 171-605 is a multi-volume user's manual for the standard version of LCOM. The Air Management Engineering Agency (AFMEA) manages the LCOM software system. Aeronautical Systems Division (ASD) also maintains a version of LCOM.

be spare parts, support equipment, facilities, or human resources.[2] An LCOM simulation is analogous to an experiment in which variations in input resources are related to variations in output. In LCOM, the most important output measure is usually the number of sorties flown. In manpower studies using LCOM, the idea is to find, for each defined Air Force Specialty (AFS), the lowest manpower level that just achieves the desired sortie rate.

We don't want manpower to be too high, because then people would be idle, or, in LCOM jargon, underutilized. But we don't want manpower to be too low either, because then people would be too busy, or overutilized. We would lose sorties as aircraft needing servicing or repair wait for maintenance crews to become available. Hence, LCOM simulation for manpower amounts to a search for a satisfactory balance between these two manpower considerations and sortie generation potential.

The details of LCOM modeling are daunting but the core ideas are few and easy to understand. LCOM can be thought of as a simple counting device. The simulation logs sorties and other performance variables from manpower levels and other resource information supplied to it by the analyst. From this perspective, to say that LCOM "determines" manpower is to speak very imprecisely. In fact, the analyst defines the manpower level. LCOM simply counts the sorties corresponding to it. The manpower versus sortie trade-off is evaluated as a queuing problem. In simple terms, if repair waiting lines become too long, more people will be added to reduce waiting times and free up aircraft more quickly. If repair waiting lines do not arise, the issue usually becomes one of constraining (or reducing) manning until they do. Here is the essence of LCOM for manpower estimation.

The analyst describes the maintenance environment through task networks and resource definitions. Air Force Specialties (AFS), with their corresponding manpower levels, are one of these resources. The analyst must also list and describe the number of aircraft, mission types, spare part levels, configuration requirements, and other information. These data are used as input to the simulation. The simulation calls for aircraft with specified configurations to be launched at particular times. If aircraft are available, they are launched. LCOM forgets about them after they're launched but remembers them when they return. If they are "broke" they are repaired. If they are not "broke" they are serviced and returned to a launch pool. LCOM counts, summarizes, and reports all resources used to do these things. The rest is detail.[3]

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[2]The term "personnel" is also used. Both terms mean people and nothing more.
[3]But, as the wit says: "God is in the details."

Why Simulation?

The Air Force has long favored a simulation approach to aircraft maintenance manpower requirements. The main reason is that mathematical work measurement methods, which are based on expected or average long run workload, do not accurately reflect aircraft maintenance realities or mission imperatives day by day. The volume of maintenance work fluctuates over time. Equipment breaks randomly, and peaks in sortie generation demand may arise suddenly. Consequently, maintenance work - and maintenance manpower - cannot be preprogrammed in expectation of an orderly and uniform production rate.

Much of aircraft maintenance work is "unscheduled" repair of equipment that breaks in a stochastic - or random - manner. Though we may be sure that aircraft components will break in the long run, we cannot be certain when they will break in the short run. Hence, to man work centers according to the long run average workload would sometimes mean inadequate sortie production in the short run. A simulation approach deals with random variations in workload by establishing a statistical basis for estimating the sortie risk of different manpower levels. If randomness in maintenance workload and spikes in sortie demands were removed, there would be little reason to simulate. A deterministic formula or other "management engineering" approach might be used instead. In LCOM, manpower is wrapped with a statistical confidence band.

LCOM is called a Monte Carlo simulation because the model makes random draws from equipment failure parameters to introduce demands for unscheduled maintenance work. Similar random draws determine how long a particular repair will take. The analyst specifies the mean, variance, and distribution types for failures rates and repair times. The model allows chance to play a role in the outcome of any given simulation trial. As a consequence, simulation trials must be run repeatedly to determine the "just right" manning level for each work center. After a satisfactory manning level is found, the model is run again using new random number seeds to determine the statistical robustness of a given manpower level. Variance reduction and other techniques can make the simulation process more efficient, but the LCOM iteration process will usually be more time consuming than a deterministic mathematical approach applied to the same modeled environment.

The interested reader will find illuminating literature on military manpower requirements particularly in Rand's work in the late 1950's and early 1960's. The work of Houston (1960, 1962) on the "personnel subsystem" concept and of Levine & Rainey (1959) on the Base Maintenance Operations Model describe the use of systems analysis tools much like the current

LCOM model for manpower planning to support Air Force systems. The technical issues surrounding maintenance manpower estimation are quite old and, for the most part, quite well studied. Newer logistics analysis methods, such as SAMSOM (Bell & Stucker, 1971) and TSAR (Emerson & Wegner, 1985) in the Air Force, and manpower tools such as MANCAP in the Army (Archer, Griffith, Laughery, Maisano, & Kaplan, 1990), attest to the enduring value of the simulation approach to logistics trade-off analysis. See also an early description of LCOM by Fisher, Drake, Delfausse, Clark, and Buchanan (1968). Readable accounts of LCOM and other military manpower analysis practices are found in Hillebrandt & Cardell (1988); Betaque, Kennelly, Nauta, & White (1978); and, especially, Binkin (1986).

LCOM Model Description

A simplified v' w of how LCOM can model the aircraft maintenance world is shown in Figure 1. Aircraft are flown, serviced, repaired, and returned to flying status according to rules defined by the analyst. The aircraft are processed through task networks that describe what the work is and what it requires. For this reason LCOM is also called a network processing model.

Maintenance resource levels in Figure 1 (i.e., spare parts, people, and equipment) are defined by the analyst, not by LCOM. In other words, these are inputs, not outputs. The model will call upon these resources, human and otherwise, in supplying aircraft to meet the flying demand. Generally speaking, if too few resources are provided, the aircraft will wait. Missions will be cancelled as maintenance queues or backlogs prevent aircraft from flying. If too many resources are provided, they will be underutilized; in effect, wasted. The statistics gathered by the LCOM simulation provide clues about how the resource levels should be changed to improve either resource economy or sortie generation potential. For a manpower study, this usually means adding manpower to reduce maintenance waiting time, or reducing manpower to improve human resource utilization.

LCOM Software

The overall structure of the LCOM software, which is written primarily in Simscript II.5, is shown in Figure 2. LCOM consists of a preprocessor program (Input Module), a simulation program (Main Module), and Post Processor Modules. In addition, a number of supporting programs are available to aid the data build-up process of LCOM. This Data Preparation Subsystem extracts and formats Air Force maintenance information from deployed aircraft to help create the LCOM task networks.

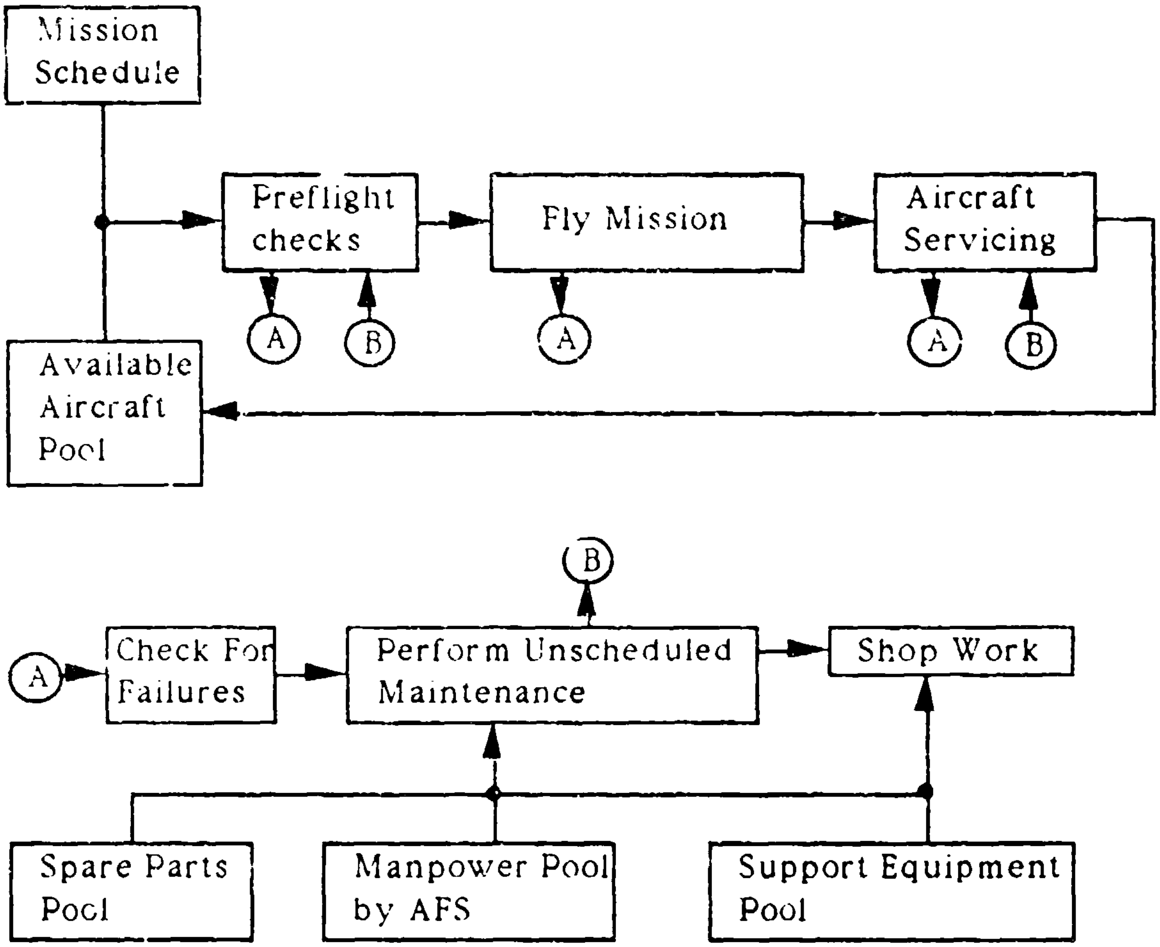

Figure 1. LCOM Simulation Logic. (Adapted from Dengler, 1981)

The various LCOM input forms (Table 1) constitute the LCOM data base. After error checking. an LCOM preprocessor converts the data into two files: the initialization ("init", in LCOM jargon) and the exogenous events (or "exog") files. The init file describes the maintenance environment to be simulated and provides starting values for the prescribed variables. The exog file contains flying schedule and related scenario data created from the mission data supplied by the user. This is what creates demand for sorties and maintenance work.

The Performance Summary Report (PSR) is LCOM's principal output. Aeronautical Systems Division's LCOM Version 89.D lists 109 PSR statistics in eight categories:

- operations (e.g., sorties flown)
- activities (e.g., average time to get resource)
- personnel (e.g., manhours used, manhours per flying hour)
- supply (e.g., number of items back ordered)

- shop repair (e.g., number of items repaired)
- AGE (e.g., aerospace ground equipments used)
- aircraft (e.g., number of aircraft days available)
- facilities (e.g., facilities used)

The Post Processor Modules produce summary statistics for the entire simulated period. These include manpower matrices showing demands for people by Air Force Specialty (AFS) by time of day, and usage and availability of spare parts, among others. The manpower matrices and parts reports are particularly important in manpower modeling with LCOM.

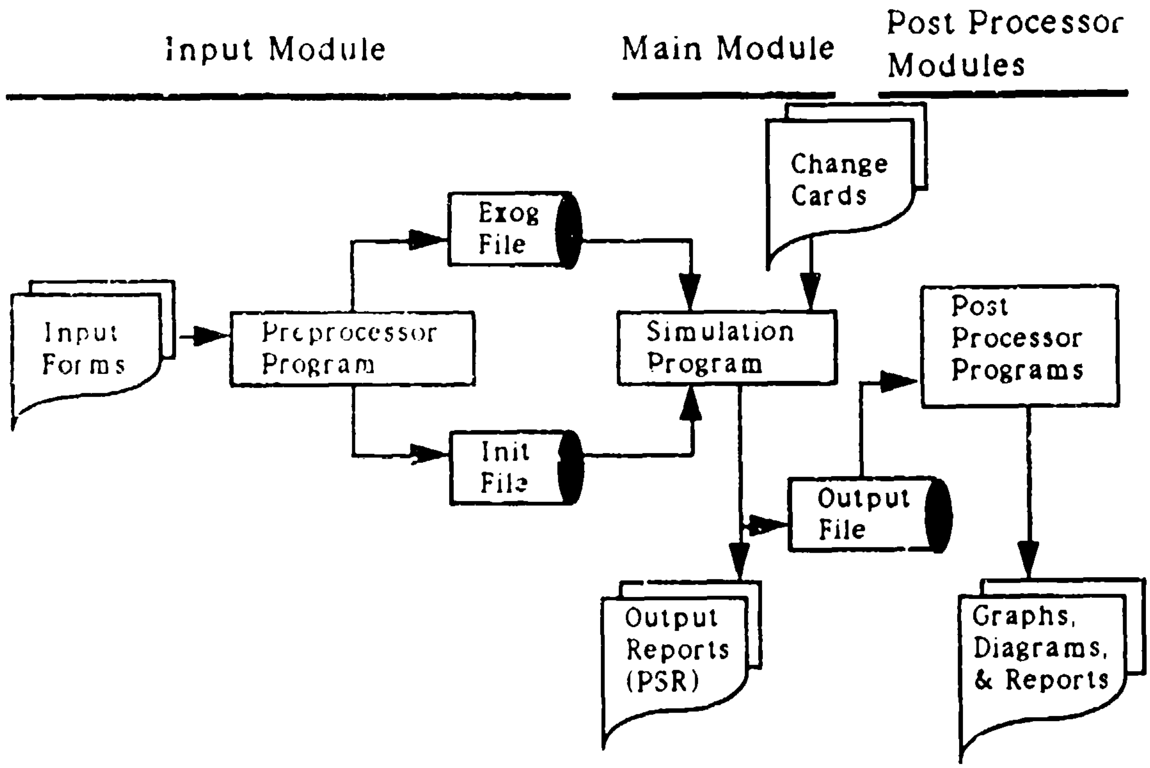

Figure 2. LCOM Software Structure (Adapted from Dengler, 1981)

The simulated work environment includes scheduled maintenance needed to fuel, arm, service, and inspect aircraft. This is described in the main servicing network. It also includes work needed to fix airplanes that have "broke" in some way. This is described in the unscheduled maintenance network. The modeled work may also include phase (periodic) maintenance, battle damage repair, and other workloads. Both organizational (flightline) and intermediate (shop) tasks are described. These are also called "on-equipment" and "off-equipment" tasks, respectively.

The analyst may define so-called maintenance action clocks for each aircraft subsystem, component, or part. The maintenance action clock "decrements" govern the rate at which

equipment fails. These failures, in turn, govern the volume of unscheduled maintenance manhours. Often, the clocks are set in mean sorties between failures, but other metrics can be used. The reliability of equipment is estimated from maintenance experience with fielded systems or from engineering data for new systems.

A common LCOM modeling scenario is to cycle aircraft in and out of the main servicing network until a maintenance action clock has breached. Then the aircraft passes through the unscheduled maintenance (repair) networks corresponding to the failed equipment item. When repaired, the aircraft returns to a mission-ready pool for assignment.

A large array of options and related "instrumentation" have been added to LCOM over the

Table 1. LCOM Input Forms

Form Name	Purpose
Task Network	Every task's name, sequence node, and selection mode
Task Definitions	Every task's name, time (mean & variance), definition, and quantity (AFS, crew size, spare part, AGE)
Resource Definitions	AFS, spare parts, aircraft, AGE, and maintenance action (failure) clocks identified
Clock Decrements	Equates equipment failure probabilities to sorties
Shift Change Policy	Defines shift length and how resources are to be allocated to shifts
Mission/Activity Entry Points	Defines resources entering the network and the required aircraft configuration allowing tracking and assignment of aircraft to missions
Priority Specifications	Describes how to handle task conflicts when using resources through preempting, expediting, and restarting rules
Sortie Generation Data	Defines mission types and other scenario data
Performance Summary Reports	Defines PSR reporting structure
Statistical Distributions	Specifies distribution types (normal, log normal, exponential, etc.)
Aircraft Assignment Search Patterns	Defines aircraft external and internal configuration search selection sequences
Internal Equipment Authorizations/Changes	Defines internal equipment, its authorization, and the network location effecting its quantities
Internal Equipment Group Definitions	Defines internal equipment groupings or combinations by aircraft
Attribute Definitions	Defines an input format for combining data on separate LCOM forms

Notes: (1) LCOM form numbers are not listed.
(2) AFS = Air Force Specialty
(3) AGE = Aerospace Ground Equipment

years. These allow the maintenance environment to be modeled with greater detail, flexibility, and realism. Even the PSR can be tailored. While these doubtless make LCOM difficult to master, they do not alter the model's "fly, fix, and figure" logic in any fundamental way. They do make it difficult to describe LCOM briefly without misleading by oversimplifying.

LCOM Task Language

In LCOM, most maintenance tasks are described as actions taken on a piece of hardware. These tasks require resources (i.e., people, parts, and AGE) and time. The actions applicable to people are:

On-equipment (Flightline)			Off-equipment (Shop)		
X	=	Access (Use AGE)	L	=	Component identification
T	=	Troubleshoot	W	=	Check/repair component
R	=	Remove and replace	K	=	Component checks OK
H	=	Inspect	N	=	Check and send to depot
M	=	Minor repair (in place)	Y	=	Disassemble/reassemble
V	=	Verify system works			
J	=	Aircraft handling			
B	=	Loading/downloading munitions			

When these action codes are paired with equipment Work Unit Codes, a concise task descriptive language is created. For example, "T74AB0" in LCOM means "troubleshoot the (F-16) radar low power RF." The entire LCOM language for unscheduled maintenance is spoken in this "action taken/work unit code" manner. For general aircraft servicing tasks and other work that cannot be tied precisely to specific equipments, words like FUEL, LAUNCH, and TOW are also used. MIL-STD 780 provides guidance on WUC numbering for aeronautical equipment.

The task descriptive vocabulary used by LCOM is exact but it is also rather limited. There is no implication in LCOM maintenance networks of what military psychologists would call task analysis. That is, the only things LCOM knows about a task is who does it, how many people are needed, who may substitute, what support equipment is needed, and how long the task takes. Through the maintenance action clocks, LCOM also knows how often a task is apt to occur. It knows nothing else about the qualitative aspects of the work. Task difficulty, personnel skills, safety considerations, and so on are not directly considered by LCOM.

LCOM Task Networks

Maintenance tasks are described in networks that define their logical flow. These networks can be defined in many different ways and in any level of detail. The task in Figure 3, for example, begins when a maintenance action clock for Part X has breached. The network section applicable to Part X is then activated. The aircraft will halt processing through the main servicing network while maintenance is performed.

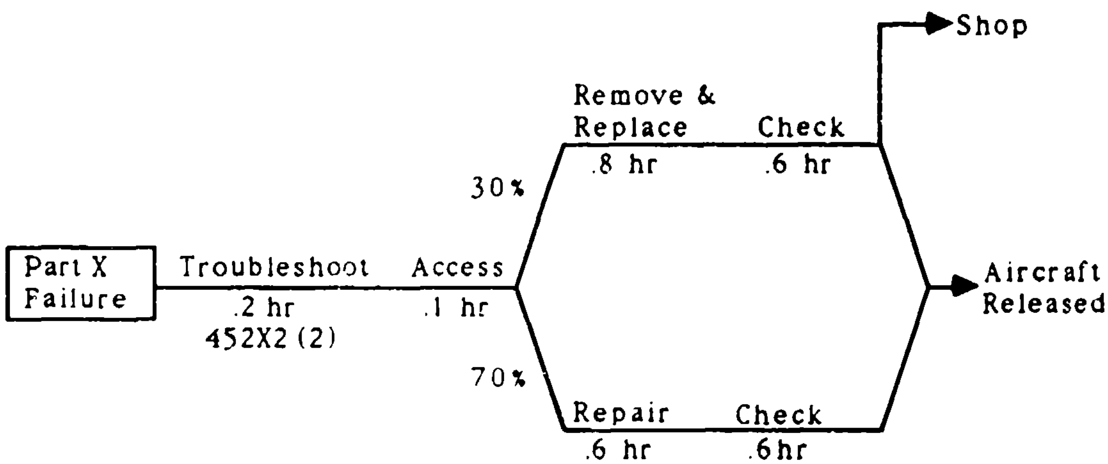

Figure 3. LCOM Network Example

The diagram shows that it takes a crew of two specialists with AFS 454X2 three tenths of an hour to identify and access the problem. A repair action taking .6 hours will result 70 percent of the time, a remove and replace action taking .8 hours 30 percent of the time. After a check, the aircraft continues processing toward mission-ready status. Shop manhours are also generated when the failed part arrives for repair. The frequency with which this network section is activated is governed by the maintenance action clock describing the equipment's expected reliability. The manhours consumed by this maintenance over the simulated period are summed. Eventually, these manhours will contribute to an LCOM manpower estimate.

One of LCOM's distinctive features is the wide array of task networking controls it provides. These can be used, for example, to:

- "call" other tasks or networks,
- create probabilistic branching (Figure 3)
- skip over or accomplish tasks in parts
- define sequential and parallel task strings
- consume and generate parts
- change the location of resources
- decrement failure clocks
- model parts cannibalization (i.e., from another aircraft)

An LCOM data base (i.e., the assembled forms) can run to several thousand lines of code for a detailed weapon system study. The bulk of this code consists of task networks, resource definitions, and task definitions. A special input coding device, the Extended Form 11, can be used to consolidate the information contained on separate LCOM forms.

Deriving Maintenance Manpower With LCOM

LCOM models are typically run for debugging purposes with resources unconstrained. This means that essentially unlimited quantities of people, parts, and equipment are made available. Initial wide-open simulation permits the analyst to confirm that sorties are being demanded, that maintenance is occurring, and that the modeled environment conforms with the data base and operational logic prescribed for it. An LCOM simulation run with unconstrained resources can be used to determine the maximum theoretical sortie performance.

But, typically, we don't want the theoretical maximum sortie rate. We want to achive a sortie rate that reflects real-world flying requirements. And, in any case, we don't have unlimited resources to work with.[4] Hence, optimization in LCOM is a process of systematically adjusting manpower levels until the sortie rate attained by LCOM settles around the desired sortie rate and other criteria, such as AFS utilization rates, stay within prescribed limits. This process is called constraining. It is through constraining that the analyst eventually finds the "just right" manpower level for each work center.

Since resources interact in such complex ways, they cannot be efficiently constrained all at once. So the usual approach is to constrain resources one at a time. For example, it would make little sense to try to optimize manpower if scarcity of spare parts and equipment prevented people from doing work. Hence, in manpower studies, attention falls first on constraining spare parts and equipment down to levels which, upon simulation, restrict performance to some pre-defined criterion.

Often, this criterion is the "Not Mission Capable - Supply" (or NMCS) rate, a statistic produced by the PSR. If the LCOM scenario specifies a NMCS rate of, say, 10 percent, the objective of parts constraining simulation trials is to establish parts levels that produce an average aircraft availability factor of 90 percent. The Post Processor Modules can produce

[4]Of course, without resource scarcity there could be no such thing as economics. LCOM would be superfluous.

reports useful for finding appropriate spare parts levels. Similar procedures can be used for equipment constraining, though AGE is less often at issue in LCOM manpower studies.

Manpower Factors

The relationship of manpower factors to sortie rate is shown in Figure 4. During manpower constraining, the LCOM analyst must consider which of these factors is driving the manpower requirement for each AFS. Other things equal, the sortie rate will govern the manpower factors.

Post Manpower: Crews dedicated to a fixed post (e.g., end of runway checks) for a fixed period and who cannot be reassigned during the work shift.

Crew Size: Each LCOM task has a defined minimum crew size. Imagine an AFS with 20 tasks in all, 19 of which require two people, and one of which requires three people. A charming LCOM locution identifies this latter task as the "maximum minimum crew size." As a general rule, manpower on at least one work shift should equal or exeed this number.

Direct Labor: The manpower level needed to accomplish the direct manhours of work generated by the simulation. It is shown as a near linear increasing function of sorties flown.

Peak Demand: Sortie demand may have an irregular pattern through the day. Massed fights or surge conditions may require many people to be working at the same time for brief periods. More people may be needed to cover these peak demands than might be provided by applying the other manning factors alone.

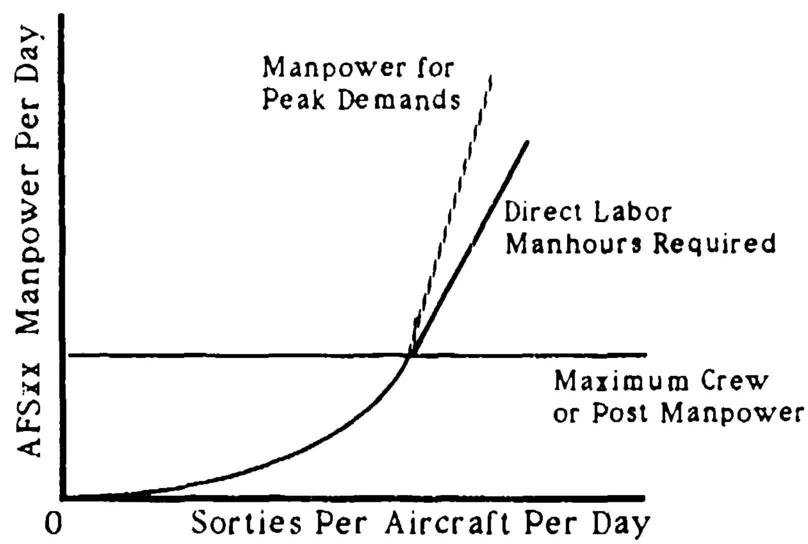

Figure 4. Manning Factors (Adapted from Dengler, 1981)

Manpower Constraining

When spare parts constraining is done, manpower constraining starts. The required manning levels for each work center (or AFS) are determined through a progressive and systematic process of manpower constraining over many simulation trials. In general, the manpower for each AFS can be said to be optimally constrained when adding manpower has no effect on sortie rate, and reducing manpower drops the observed sortie rate below the desired sortie rate. This process of allocating and reallocating manpower calls upon LCOM statistical reports as well as the analyst's judgment.

Dengler (1981) describes the following method. In the equation, manhours used by each AFS

$$M(s) = \frac{\text{AFS Manhours Used}}{(\text{Utilization Factor}) \times (\text{Number of Days}) \times (\text{Shift Length})}$$

are converted to the average daily number of people required for a shift [M (s)] by taking shift length, days simulated, and manpower utilization or availability factors into account. Utilization factors are specified as the percent of available manhours that can be allocated for direct work. The upper limits vary by AFS, but average about 80 percent. The per-shift manning levels so derived become starting values for manpower constraining runs. AFS manning should not be lower than the maximum minimum crew size if no AFS substitution rules have been defined.

The number of days to be simulated, the simulation run time, must be large enough to ensure a steady state condition. The observed values for failures, repair times, and other LCOM criteria should come close to their expected values shown in the LCOM data base. The sortie rate target and the number of PAA (Primary Authorized Aircraft) for the simulation must be taken into account. Dengler (1981) has a rule of thumb for fighters recommending 112 days for a 24-PAA unit and 38 days for a 72-PAA unit. Both of these yield about 2,000 simulated sorties.

An LCOM simulation is performed using so-called "change cards" which list resources "authorized" for the run. The analyst is guided in setting manning levels for subsequent LCOM runs by monitoring the sortie rate, manpower utilization, and other statistics associated with a given manning level. Work centers that may need additional manpower can often be identified by examining the Manpower Matrix Post Processor, which shows AFS "back order" statistics. The analyst must determine whether repair delays in particular work centers[5] are constraining the

[5] The terms work center and AFS are nearly interchangeable in LCOM. An AFS is a specialty's name (e.g., integrated avionics technician); an AFSC is a Specialty Code (e.g., 452X1). A work center is an organizational and accounting entity, such as an avionics intermediate shop.

sortie rate. Such repair delays might be tolerated if they are not causing sortie bottlenecks that lead to missed sorties. On the other hand, work center manning might be reduced if the average utilization rate falls below established standards and if the sortie rate does not suffer as a result.

Finally, the actual manpower - the bottom line. After the analyst has completed all AFS manning adjustments and satisfied himself through confirmatory LCOM runs that he has reached the optimal manpower levels for each AFS, he has one final calculation to make. The number of authorizations (i.e., the number of whole people to be listed on manning documents) for each AFS depends on the total daily LCOM requirement for all shifts, the monthly manpower availability factor, the work days per month, and the shift length. The equation below shows how this calculation is made.

$$M = \frac{\begin{array}{c}\text{Average Daily}\\ \text{LCOM Derived}\\ \text{Manpower}\end{array} \times \begin{array}{c}\text{Work Days}\\ \text{Per Month}\end{array} \times \begin{array}{c}\text{Shift}\\ \text{Length}\end{array}}{\text{Manpower Availability Factor}}$$

The term "whole people" above is used advisedly. Division with fractional manpower availability factors (e.g., 244.8 hours per month for wartime) will produce fractional manpower requirements. Since we can authorize people only in whole (integer) units, tables for rounding these fractions into whole-person equivalents are used.

Certain Matters

Manpower Availability and Utilization. Availability is the number of hours per month a person can be allocated to a duty post. For peacetime, 144.5 hours is used;. for wartime, 244.8 hours. Utilization is the percentage of a person's duty time that can be allocated to direct work. There are published standards for both utilization and availability. Manpower requirements computed from LCOM - and from other methods - must take both factors in account since both influence manpower requirements. LCOM evaluates shift manning levels. These LCOM manpower levels must be scaled up to arrive at the actual number of people to be authorized.

AFS Task Inventory. LCOM data bases describes only direct maintenance work. The indirect work maintenance people do is accounted for through the manpower utilization factors, but the work itself is not described. Hence, LCOM data bases will not normally contain a complete inventory of the work of each specialty.

LCOM vs. Standard Manning. In general, only those work centers whose manning levels directly constrain sorties are modeled in LCOM. Shop overhead, maintenance management, and certain off-equipment AFSs are excluded for this reason. Depot manpower is likewise excluded. About half of unit-level maintenance manpower is derived with LCOM across the Air Force. (See Furry, Bloomberg, Lu, Roach, & Schank, 1979.) The rest of the maintenance manpower requirement is determined by application of manpower standards or by other means.

LCOM Data Base Support. LCOM data bases are created in part from the Air Force Maintenance Data Collection (MDC) System. A number of computer programs have been created to process these data into LCOM format. The newer Reliability and Maintainability Information System (REMIS) and Core Automated Maintenance System (CAMS) are also being used for LCOM studies. These ancillary programs are an important part of the LCOM system used by the Air Force. The LCOM Data Preparation Subsystem - formerly known as the Common Data Extraction Programs, or CDEP - could be called LCOM's front porch. Recently, a Simscript II.5 program that extracts and formats MIL-STD 1388-2A (Logistics Support Analysis Record - LSAR) task data for use in task networks has been added to the ASD version of LCOM.

LCOM Audit. A so-called "Operational Audit" is conducted to verify the simulated maintenance environment. LCOM technicians will visit operating bases for the weapon system under study to check the accuracy of MDC data, verify AFS-task assignments and crew sizes, determine maintenance procedures and task times, and so on.

LCOM Software Vintage. LCOM is basically a 1960's style "batch" system. It is not very user-friendly. Until recently, LCOM was confined to mainframe computers. Many Air Force users now run LCOM on IBM 9370 super mini's. Some run LCOM on VAX 11/780 series machines. The LCOM software has recently been reported to be running on an Intel 80386 microprocessor-based personal computer. Proposals for rewriting, compressing, and updating the LCOM code to make it more user-friendly and efficient are sometimes heard. The "LCOM 2000" study (Dymond, Hinds, Hopple, Gunkle, Schadle, & Bergeron, 1987) discusses these LCOM improvements in some detail.

LCOM Substitutes. The basic queueing processes and simulation logic of LCOM can be easily replicated by any number of competing methods. SLAM (Simulation Language for Alternative Modeling) and Micro-SAINT are well known examples. The Army Research Institute's MANCAP (Manpower Capabilities Predictor), one of the new HARDMAN III tools, was inspired by LCOM. But LCOM remains unique. Its analytic flexibility, attention to detail,

range of application, and data base support far exceed those of any potential substitute within its domain. For a given study, equivalence of model [illegible] might mean equivalence in model credibility, but LCOM findings still tend to be used as the standard for comparing manpower results.

An LCOM Sampler

The LCOM process lends itself to innovative applications. LCOM has been used with other models and it has been extended to systems other than aircraft and to the other Services.[6] The applications discussed below convey some idea of LCOM's use within the MPT domain.[7]

LCOM in Acquisition. LCOM has been paired with comparability analysis to produce early estimates of maintenance manpower for new systems. The work of Tetmeyer (1974) and his colleagues at the Air Force Human Resources Laboratory and at the Aeronautical Systems Division of Air Force Systems Command is the best known example. The comparability approach pioneered by Tetmeyer is now prescribed by Logistics Support Analysis (MIL-STD 1388-1A). The basic idea is to create a baseline equipment configuration for a new system by using subject-matter experts to identify existing systems that are most like the projected new system. Tetmeyer's approach emphasizes the development of equipment reliability "deltas" which are used to adjust LCOM failure clocks. The notion of baseline comparison systems so prominent in MPT analysis for new systems is rooted in this LCOM-oriented work. (See also Maher & York, 1974; Tetmeyer & Moody, 1974; and Tetmeyer, Nichols & Deem, 1976.)

The "Skill Level Problem." LCOM modeling assumes that all people within an AFS will perform a task in the same way. Every person is assumed to be task qualified and to take the same amount of time to do a task. Howell (1981) showed what could happen if "three-levels" (inexperienced people) predominated the work force. He adjusted the LCOM task times using subject-matter expert judgments comparing "three-levels" against "five-levels" (experienced people). LCOM projected much larger manpower requirements with the "three-level" work force since inexperienced people were judged to require more time to do the same work as "five-level" people. Garcia & Racher (1981) attempted to incorporate Air Force occupational survey data on task difficulty and time spent on maintenance tasks identified in LCOM and obtained similar results.

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[6] In theory, any production system that can be described with queues and servers could be modeled with LCOM.
[7] MPT is, of course, only one application for LCOM. The model is used at ASD for other Integrated Logistics Support (ILS) elements including spare parts, support equipment, repair policy, and reliability analyses for new systems.

Job Performance Aiding Technology. The work force scenario modeled by Howell was modeled in reverse in a recent study by Boyle, Plassenthal, & Weaver (1990). Suppose a well-designed job performance aid (JPA) led to more accurate maintenance troubleshooting. If it did, troubleshooting time for maintenance tasks might be reduced. For a given maintenance scenario, this should lead to a reduction in overall maintenance manhours, and hence manpower requirements. Potential ask time effects of an advanced technology job performance aid, AFHRL's Integrated Maintenance Information System (IMIS), were modeled using LCOM. Troubleshooting times for all on-equipment tasks were systematically reduced using an LCOM data base description of a baseline configuration for an new Air Force fighter. For a given sortie rate target, LCOM manpower requirements were found to decline sharply when troubleshooting times were cut in half across the board. Of course, whether IMIS (or other) innovations really produce such beneficial effects cannot be determined with LCOM (or other) models alone. But LCOM is a sensitive tool for calibrating the potential manpower effects of modern JPA technology. LCOM "what if" modeling vividly illustrates the importance of obtaining empirical performance data on the effects of new maintenance technology like the IMIS.

MPT Integration. The LCOM process has been expanded by the SUMMA (Small Unit Maintenance Manpower Analyses) model to serve as a platform for integrated manpower, personnel, and training analysis for maintenance. The SUMMA model (Boyle, 1990) uses LCOM task data supplemented with subject-matter expert judgment to identify improved AFS-task alignments. The objective is to limit manpower requirements, especially for small unit deployments, by enlarging maintenance jobs. SUMMA provides an MPT projection model which informs the analyst of potential aptitude, training, and cost impacts of job merger options. An analytic manpower forecast is also provided for any given policy of AFS job definition. LCOM upload and download utilities are included in the microcomputer-based SUMMA package. The SUMMA model ties MPT trade-off analysis to altered AFS job definition policies, and ties these, in turn, to LCOM.

References

Aeronautical Systems Division (ASD). (1990). LCOM version 89.D user's manual. Wright-Patterson Air Force Base, OH: Deputy for Engineering.

Archer, R., Griffith, W., Laughery, R., Maisano, R., & Kaplan, J. (1990). Tools for predicting manpower requirements and system availability: the maintenance manpower analysis (MMAA) and the manpower capabilities predictor (MANCAP). Proceedings, 58th MORS Symposium. Annapolis, MD: United States Naval Academy.

Bell, C., & Stucker, J. (1971, May). A technique for determining maintenance manpower requirements for aircraft units. (R-770-PR, AD 733561). Santa Monica, CA: The Rand Corporation

Betaque, N., Kennelly, D., Nauta, F., & White T. (1978, December). Manpower planning for new weapon systems. (AD A066928). Washington: DC: Logistics Management Institute.

Binkin, M. (1986). Military technology and defense manpower. Washington, DC: The Brookings Institution.

Boyle, E. (1990, April). SUMMA summary. (AFHRL-TP-90-XX). Wright-Patterson Air Force Base, OH: Logistics and Human Factors Division, Air Force Human Resources Laboratory.

Boyle, E., Plassenthal, J., & Weaver, W. (1990, June). Manpower impacts of job aiding technology. (AFHRL-TP-90-XX). Wright-Patterson Air Force Base. OH: Logistics and Human Factors Division, Air Force Human Resources Laboratory.

Dengler, D. (1981, December). LCOM II student training guide. (AFMSMMET Report 81-2). Wright-Patterson Air Force Base, OH: Air Force Management Engineering Agency.

Drake, W., & Wieland, B. (1982, March). LCOM simulation software users reference guide. (AFMSMMET Report 81-1). Wright-Patterson Air Force Base, OH: Air Force Management Engineering Agency.

Dymond, L., Hinds, B., Hopple, G., Gunkel, R., Schadle, W., & Bergeron, P. (1987, May). Analysis of LCOM capabilities final report. Washington, DC: Synergy, Inc. (AF Contract F49642-85-D0035).

Fisher, R., Drake, W., Delfausse, J., Clark, A., & Buchanan, A. (1968, May). The Logistics Composite Model: an overall view. (RM-5544-PR). Santa Monica, CA: The Rand Corporation.

Furry, W., Bloomberg, K., Lu, J., Roach, C., & Schank, J. (1979, April). MANPOWER: A model of tactical aircraft maintenance personnel requirements. (R-2358/1-PA&E). Santa Monica, CA: The Rand Corporation.

Garcia, R., & Racher, J. (1981). An investigation into a methodology to incorporate skill level effects into the Logistics Composite Model. (LSSR 29-81, AD A105131). Wright-Patterson Air Force Base, OH: Air Force Institute of Technology.

Hildebrandt, G., & Cardell, N. (1989, July). Analysis of models linking skilled maintenance manpower to military capability. (R-3619-FMP). Santa Monica, CA: The Rand Corporation.

Houston, M. (1960, December). Concepts for estimating Air Force manpower requirements for planning purposes. (RM-2611, AD 250725). Santa Monica, CA: The Rand Corporation.

Houston, M. (1962, February). Manpower planning factors for Air Force systems in the conceptual stages of development. (RM-2823-PR). Santa Monica, CA: The Rand Corporation.

Howell, L. (1981, August). Manpower forecasts and planned maintenance personnel skill level changes. (ASD-TR-81-5018). Wright-Patterson Air Force Base, OH: Aeronautical Systems Division.

Keller, K. (1977, July). Logistics Composite Model student training text. Langley Air Force Base, VA: 4400 MES/LC.

Levine, R, & Rainey, R. (1959). The base operations model used in Rand logistics research. (RM-2374, AD 220605). Santa Monica, CA: The Rand Corporation.

Maher, F., & York, M. (1974, December). Simulating maintenance manning for new weapon systems: maintenance manpower management during weapon system development. (AFHRL-TR-74-97, AD A011986). Wright-Patterson Air Force Base, OH: Advanced Systems Division, Air Force Human Resources Laboratory.

Richards, E. (1982, July). Building and operating the Logistics Composite Model for new weapon systems. (ASD-TR-82-5033). Wright-Patterson Air Force Base, OH: Aeronautical Systems Division.

Tetmeyer, D., & Moody, W. (1974, December). Simulating maintenance manning for new weapon systems: building and operating a simulation model. (AFHRL-TR-74-97 (II), AD A011987). Wright-Patterson Air Force Base, OH: Advanced Systems Division, Air Force Human Resources Laboratory.

Tetmeyer, D. (1974, April). Estimating and controlling manpower requirements for new systems: a concept and approach. (AFHRL-TR-74-31, AD 778838). Wright-Patterson Air Force Base, OH: Advanced Systems Division, Air Force Human Resources Laboratory.

Tetmeyer, D., Nichols, S., & Deem, R. (1976, May). Simulating maintenance manning for new weapon systems: maintenance data analysis programs. (AFHRL-TR-74-97 (III), AD A025342). Wright-Patterson Air Force Base, OH: Advanced Systems Division, Air Force Human Resources Laboratory.

United States Air Force. (1987). Air Force Regulation 25-7. Logistics Composite Modeling.

United States Air Force. (1985). Air Force Manual 171-605. Logistics Composite Modeling (LCOM) System. (Multiple volumes)